Technology Map
Chromate Control and Alternatives

Version 1

July 2008

Keith Legg, Rowan Technology Group
(847) 680-9420; klegg@rowantechnology.com

Instructions

- Important: You may need to enable macros to use some features
  - Click Tools/Macros/Security and select Medium on the Security Level tab
  - When opening the Map you may be asked to Enable or Disable Macros. Click Enable
- **This document only works in Slide Show mode**
- Navigation is done by clicking on symbols on the slides:
  -  Return to last viewed slide
  -  Return to Table of Contents
  -  Return to Current Usage table
  -  Link to another slide
  -  Link to a document (usually PDF
  -  Link to qualified engineering data
  - Blue underlined text: Link to web location

TOC

SERDP
Strategic Environmental Research and Development Program

ESTCP
Environmental Security Technology Certification Program

Table of Contents

SERDP
Strategic Environmental Research and Development Program

ESTCP
Environmental Security Technology Certification Program

Current chromate usage

Current process	Usage	ESOH
Hard chrome plating	**OEM** /Wear, depot rebuild/ Hydraulics, landing gear, turbine engines, gun barrels	Cr^{6+} chromic acid, fumes, waste. OSHA, EPA
Chromate conversion - Al	**OEM/Depot** /Corrosion, paint adhesion/ Aircraft skins, vehicle & aircraft structural Al	Cr^{6+} coatings. Aircraft painting. OSHA, EPA , RoHS, REACH
Chromate sealing - coatings	**OEM/Depot** /Corrosion, paint adhesion/ Cd, Zn, Al, anodize /Fasteners, connectors, hydraulics, landing gear	Cr^{6+} coatings. OSHA, EPA , RoHS, REACH
Chromate conversion – Mg	**OEM/Depot** /Corrosion, paint adhesion/ Gearboxes, pump casings (vehicles, aircraft)	Dow 9, Dow 17 Cr^{6+} coatings. OSHA, EPA , RoHS, REACH
Chromate wash	**Army depot** /Corrosion, paint adhesion/ Steel panels	Cr^{6+} fumes, waste. OSHA, EPA, RoHS, REACH
Chromated primer	**OEM/Depot** /Corrosion/ Aircraft, vehicles, interior, exterior (+fuel tank internal coatings)	Cr^{6+} fill. OSHA, EPA , RoHS, REACH
Chromic acid anodize	**OEM/Depot** /Corrosion, paint adhesion/ Structural Al	Cr^{6+} fumes, waste. OSHA, EPA
Chromated sealants	**OEM/Depot** /Sealing, corrosion, EM emission/ Joints in aircraft, vehicles, structures	Cr^{6+} fill, waste. OSHA, EPA , RoHS, REACH
Metallic-ceramics	**OEM/Depot** /Corrosion, oxidation, abrasion/ GTEs, some landing gear and structures	Cr^{6+} fill, Cr^{6+} fumes, waste. OSHA, EPA , RoHS

TOC

SERDP
Strategic Environmental Research and Development Program

ESTCP
Environmental Security Technology Certification Program

HARD CHROME PLATING

TOC

SERDP
Strategic Environmental Research and Development Program

ESTCP
Environmental Security Technology Certification Program

Options - Hard chrome plating

Substitution, control options					Best DoD options	Projects			Gaps	Implementation
Current tech Options	Commercial Status	DoD Status								
		R&D	Qual	Prod		Unsuccessful	On-going	Successful		
HVOF	All OEM mil and comm landing gear. some GTEs, acts	Being implemented at OO-ALC. Depot some GTE usage			✓	ESTCP HCAT HVOF: Completed			Spall-resistant coating for carrier a/c LG	A/c LG – new/MRO; hydraulics
Electroless Ni (internals)	Primary ID alt. Moderate and growing use, F-35	Some R&D, testing			✓	AFRL NLOS completed, Niplate 700. Not implemented			No qual ID chrome alt	Hydraulic IDs
Ni-based plate	Limited OEM use									
Other electroplates	Limited OEM use Co electroplates - GTEs	nCo-P electroplate dem/val, JAX			✓	SERDP nCo-P				
						ESTCP nCo-P D/V				
Gas/ion nitride	Some actuator rod				N/A					
Cr^{3+} electroplate	Decorative only				N/A					
Ta (gun barr, large)		Dem/val, firing test			TBD	"green gun barrel"			Qual alt for gun barrels	
Ta (gun barr, small)		R&D				SERDP CVD				
Ta (gun barr, small)		R&D				SERDP expl clad				
CONTROL OPTIONS										
Segregated line		In use (FRC-SE)			✓				Fit	FRC-SE
Enclosed line		In planning (WR ALC)			✓				Cost	
Surfactants		In use								

Description, current technology – Hard chrome plating

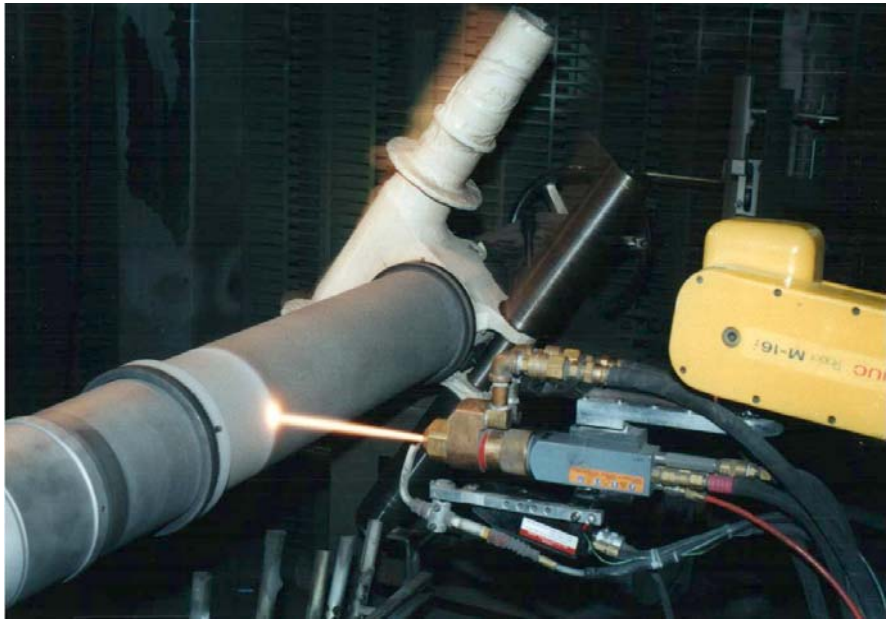
Technology and usage

- Chromium plating from chromic acid bath
- OEM usage
  - Wear resistant coatings on components of aircraft, vehicles, ships
    - Hydraulic actuators, landing gear, valves, etc.
  - Typical thickness 0.003”
- MRO, depot use
  - Rebuild to spec
    - Hydraulic actuators, landing gear, GTEs, ship steering rams, etc.

ESOH and technical issues

- Cr^{6+} fumes
  - Worker exposure, air emissions
- Maintainer exposure
- ESOH regulations
  - OSHA Cr^{6+} PEL
  - EPA Clean Air Act
  - Potential REACH for use in EU
- Note: Chrome plate is not toxic, only plating solution and emissions

Description – High Velocity Oxy-Fuel spray (HVOF)



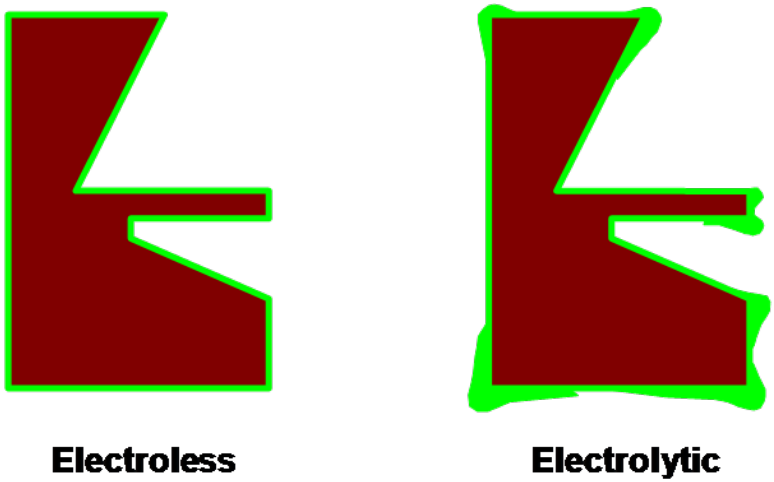
- Method of choice for hard chrome replacement on aircraft
- Gaining use in heavy vehicles and mining equipment

- Torch produces a hot, supersonic oxy-fuel flame
  - Oxy-hydrogen, oxy-kerosene or other fuel torch
- Powder (e.g. WC-Co) injected into flame
  - Softens, splats onto the substrate
- Rapid build-up
  - Can coat landing gear cylinder in 30 min
- No embrittlement
  - No hydrogen bake needed for high strength steels

Click for additional Info

TOC

Description – Electroless Ni



Electroless Electrolytic

- Deposited in tank from solution without use of electric current
- Excellent uniformity and ability to plate into deep holes and slots
- Must be heat treated (350-400C) for max hardness
- Not as wear resistant as EHC
- Fatigue depends on bath age

- EN choices
  - Low P (3%) for highest as-deposited hardness
  - High P (10-12%) for best as-deposited corrosion resistance
- Modern baths with automatic chemistry addition must be used
  - Consistency
  - Build-up
- Composites available with hard particles or Teflon
  - Generally not recommended except for lubricity

Click for additional Info

Description – nCo-P and other pulse plating technologies

nCo-P

- Developed under SERDP PP-1152 by Integran Technologies, Inc., Toronto
- Monopolar pulsing (on/off) to create nanograin material
- Hardness 600-700VHN as-depos, 1000-1200 after 400C heat treat

Other plating technologies

- Composites with hard particles (SiC, diamond, etc) in various electro- and electroless plates (Ni, EN, nCo-P)
  - Reduced wear, but generally not recommended by Rowan due to process and uniformity issues
  - Several evaluated in AFRL NLOS and ANLOS programs
- Other pulse plating technologies commercially available but unproven
  - Faraday Technologies
  - Xtalic

Status – HVOF

Commercial/OEM

- Specified on all new landing gear programs
  - B787, B767-400, A380, A350
  - F-35 (all variants)
- Increasing use for hydraulics
  - Aircraft (OEM, MRO)
  - Caterpillar vehicle hydraulics (OEM, MRO)
- Specifications
  - AMS 2447, 2448, 2449
  - Boeing 5851

DoD

- Project to replace all EHC on LG at Ogden ALC
  - 38-128 qualified so far
- Advanced testing, Qualifications
  - Flight testing EA-6B (JAX), CH-53 (FRC-E)
  - C-2, P-2, P-3, C-130 propeller hubs WR-ALC, FRC-E
  - H-1 drive and rotor components, FRC-E
  - P-3 LG (FRC-SE) qual'd but not in production
  - TF33 GTE (OC-ALC)

Status – Electroless Ni

Commercial/OEM

- Widely available industrially
- Increasingly used in aerospace as hard chrome alternative, especially for IDs and complex shapes
- Used on F-35 as EHC alternative where HVOF cannot be used
  - Mostly low-P EN, some EN-PTFE

DoD

- Depot interest in recent years
  - No known depot implementation
  - Older baths difficult to operate, could not be used for rebuild
- In past difficult to use and not viable for build-up
  - Modern chemistry and automated systems easier to use
  - Rebuild thickness now possible
  - Adhesion tricky

Status – nCo-P and other plates

Commercial/OEM

- nCo-P not yet qualified
- Validated as thin dense Cr alternative for F-35 3BSM actuator hydraulic ID (Smiths Aero)
  - Not in production as no vendor
- Current licensee – Enduro for hydraulic rod coating
- Other electroplates
- Praxair Tribomet (Cr_3C_2-Co) small production use in GTEs

DoD

- ESTCP Dem-val project for nCo-P ongoing at FRC-SE (JAX)

Projects, data – HVOF

Projects

- All ESTCP HVOF projects complete
  - Landing gear
  - Hydraulic actuators
  - Gas Turbine Engines
  - Helicopter Dynamic Comps
  - Propeller Hubs
- Powdermet coating for higher strain-to-failure (earmark)
  - Si_3N_4-CoCr
    - Start July 08
- Goodrich LG HVOF WC-CoCr in-house integrity evaluations, F-35
- Project to replace all EHC on LG at Ogden ALC
  - 38-128 qualified so far

Data

- Project reports – see left column
- Design Guidelines
- All engineering data available at www.materialoptions.com

Projects, data – Non-HVOF

Projects

- SERDP PP-1152 – nCo-P
  - Complete – developed nCo-P
- ESTCP WP-0411 – nCo-P
  - Dem-val Integran and JAX
- Gun barrels
  - SERDP sputtered Ta
  - SERDP WP-1425 CVD Ta
  - SERDP WP-1426 explosive clad
- JSF nCo-P TDC alternative
  - Developed, validated for IDs (Smiths Aero, UK)
- AFRL NLOS
  - Recommended NiPlate 700 (EN+SiC) – not implemented
  - ANLOS (no-Ni) ongoing

Projects (cont)

- SERDP WP-1147 Electrospark alloying – not satisfactory
- SERDP WP-1151 ID Plasma spray – not satisfactory

Data

- Engineering data not yet available for any non-HVOF alternatives
- Initial test data (see Projects, left)
  - EN and composites (AFRL NLOS)
  - nCo-P (SERDP P-1152)

SERDP
Strategic Environmental Research and Development Program

ESTCP
Environmental Security Technology Certification Program

Implementations – Hard chrome alts

Alternative	Organization	System	Subsystem	Notes
HVOF				
HVOF WC-10Co4Cr	Lockheed, Goodrich	F-35, CTOL, STOVL, CV	Landing gear, actuator rods, miscellaneous wear surfaces	In production for all landing gear components. Almost no hard chrome on weapons system
	Boeing	C-17	Nose landing gear steering post shelf	HVOF used to solve severe wear issue
	All new commercial landing gear programs manufactured in US and Canada:			
	Boeing, Goodrich, Messier-Dowty	767-400, 787	Landing gear	All components replace hard chrome with HVOF
	Airbus	380, 350	Landing gear	All components replace hard chrome with HVOF
HVOF WC-17Co	Ogden ALC	A-10, F-16, B-1, T-38, F-15 C/D, E, KC-135, C-130, C-5, B-52	Landing gear	38 components converted to date. OO-ALC plans to convert all OD hard chrome to HVOF
Electro- and electroless plates				
Electroless Ni-P	Lockheed, Goodrich	F-35, CTOL, STOVL, CV	Miscellaneous interior wear surfaces	

Best current options, gaps – EHC

Substitution

- HVOF
  - Externals and shallow internals
    - Typical depth/dia up to 1/1
  - Greatly superior performance
  - Not for high strain parts
- Internals
  - nCo-P electroplate being validated at JAX
    - SERDP project complete
    - ESTCP project in progress
  - Other plating options
    - Electroless Ni-P

Control

- Surfactants to reduce tank emissions
- Isolate EHC line from rest of shop
  - Done at FRC-SE (JAX)
- Enclosed plating line
  - Designed for WR-ALC (not yet implemented)

Gaps

- HVOF – Coating that does not spall at high thickness, high load for Navy carrier a/c
- Qualified ID alternative for MRO
- Qualified alternatives for gun barrels

SERDP
Strategic Environmental Research and Development Program

ESTCP
Environmental Security Technology Certification Program

CHROMATE CONVERSION

TOC

SERDP
Strategic Environmental Research and Development Program

ESTCP
Environmental Security Technology Certification Program

Options – Chromate conversion of coatings and Al alloys

Substitution, control options				Best DoD options	Projects			Gaps	Implementation
Current tech Options	Commercial Status	DoD Status			Unsuccessful	On-going	Successful		
		R&D	Qual / Prod						
Trivalent chrome conversion	All vehicles and electrical equipment (EU ELV and RoHS compliance). Incs Al alloys; Zn, ZnNi coatings.	NAVAIR qualified: TCP		✓			ESTCP Non-Chromate Al pretreatments	Better treatments for 2000 and 7000 series Al alloys. Electrical cabinets. Bonding primers. Fasteners	Helos, EFV, Army vehicle road wheels
		Electrical performance under test (DDG 1000)							
Non-Cr conversion		NASA, TACOM, USMC: Alodine 5200 5700		✓					
Paint adhesion promoters (sol-gels, Prekote)	Boeing production	USAF flight testing: Prekote		✓					
Phosphate	Production (steel sheet)	Army vehicles		✓				Wash primers	
Polymer coatings	Production (steel sheet, Kobe Steel)						SERDP electroactive polymers		

Description, current technology – Chromate conversion

Technology and usage

- Solution containing sodium dichromate or other chromates wiped, sprayed or dipped
  - Chemical conversion of surface
  - Provides self-healing corrosion protection
- Usage
  - Al, Mg alloy corrosion protection
  - Al aircraft skins
  - Sealing of corrosion-resistant coatings (Zn, Cd, Al, ZnNi, etc)
  - Sealing of anodized surfaces
  - Paint adhesion

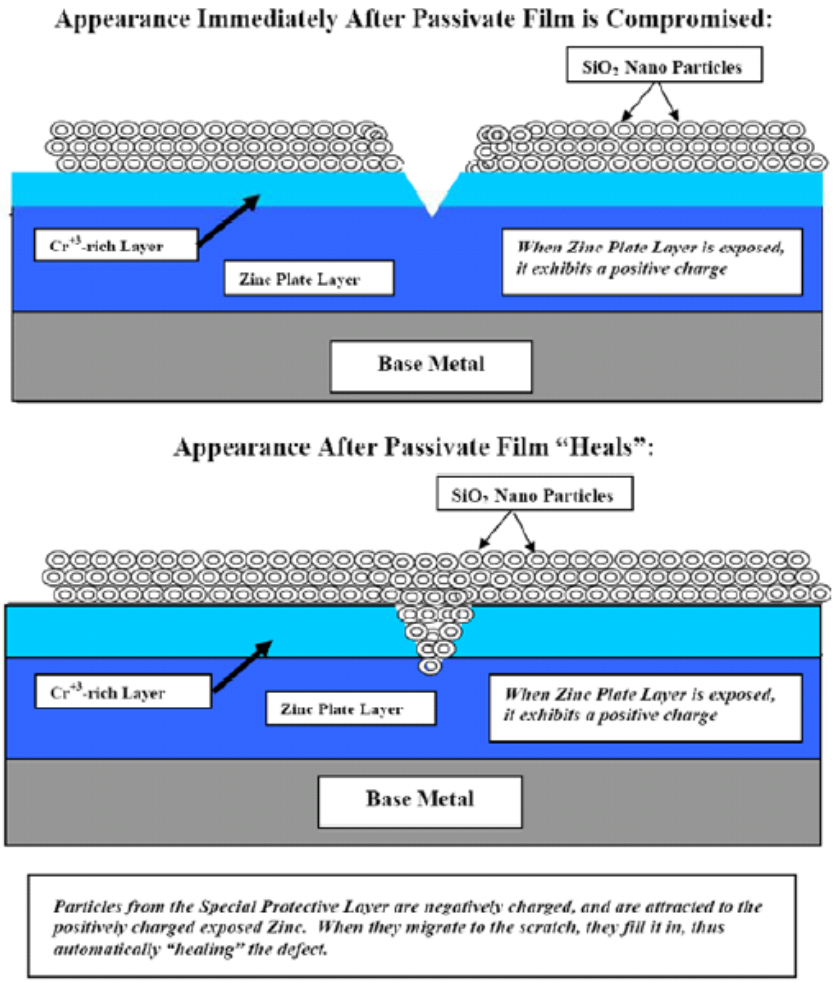
ESOH and technical issues

- Worker exposure during OEM and MRO
- Maintainer exposure during scuff-sand and repaint
- Regulations
  - EPA Clean Air Act
  - OSHA Cr^{6+} PEL
  - ELV, WEEE, RoHS, REACH

Description – Tri-chrome treatments

- Developed by NAVAIR and tested under ESTCP WP-0025
- Drop-in replacement for Cr^{6+} conversion coatings/sealers
- Cr^{3+} with Zr inhibitor
- Licensed and sold as
  - B-K Aklimate
  - Lusteron Aluminescent
  - Iridite TCP
  - Metalast TCP HF
  - Surtec ChromitAl TCP
- Other Cr^{3+}, such as Alodine 5900
- Commercial systems now often contain Co inhibitors and SiO_2 nanoparticles

Click for additional Info



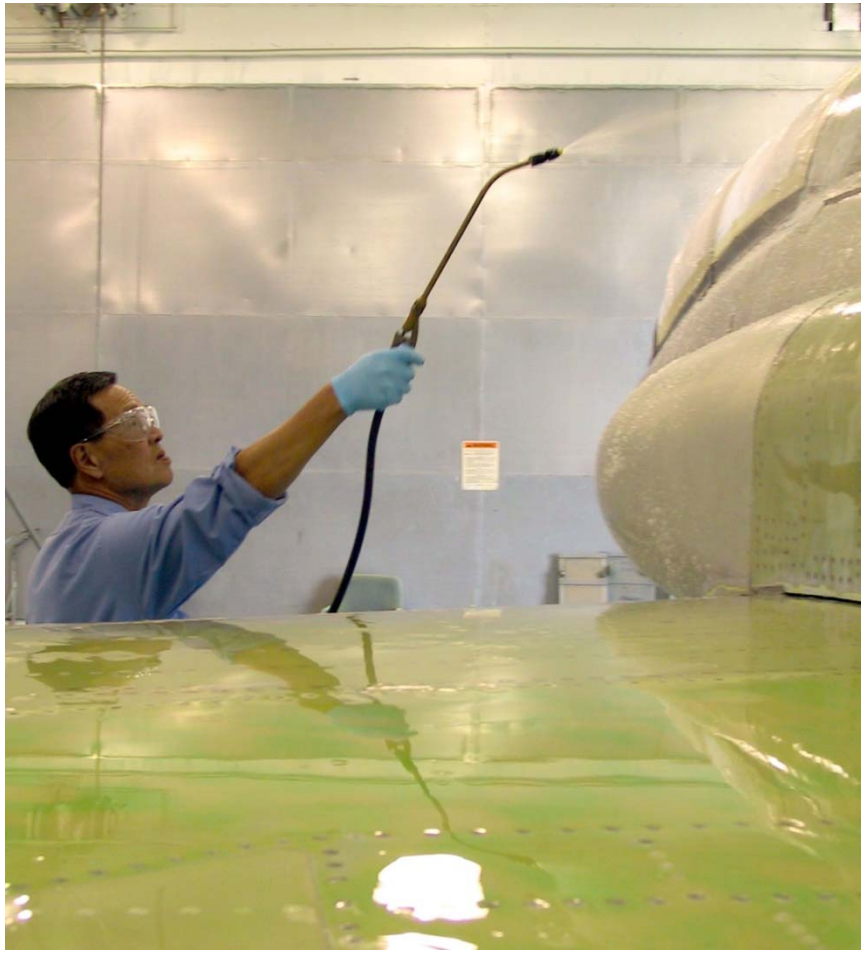
TOC

Description – Non-Cr treatments

- Various inhibitors
  - Permanganates, borates
  - Zr, Mo, Co, Mn
  - Rare earths, Ce or rare earth "cocktails"
  - No Cr^{3+}
- Commercial products include
  - Alodine 5200/5700
  - Atotech Uniprep, Interlox
  - Iridite NCP (NAVAIR license)

Description – Adhesion promoters

- Designed to improve paint adhesion
  - Do not provide corrosion protection
  - Cannot be used alone
- Sol-gels (Boegel)
  - AC130/131, Alodine 6000 SG
  - Prekote
- Others
  - Oxsilan 0500 organo-silane
  - Chemidize 727



Status – Tri-chrome sealers

Commercial/OEM

- Commercial uses – Various Cr^{3+} and non-Cr alternatives adopted to comply with ELV, WEEE, RoHS
  - Aircraft
  - Vehicles
  - Electronics
  - Fasteners
  - Al alloys
  - Auto and electronic coatings (Zn, ZnNi, ZnFe etc)

DoD

- Authorized under chromate primer
  - Alodine 5900 in production for skins of all Navy helicopter MRO at FRC-E since Jan 2006
  - Same for JAX, NI
  - All FRC component immersion sealing
- FRC-SE (JAX) plans implementing TCP for anodize sealing end 2008
- AMCOM authorized for all missile and aircraft coatings
  - Full implementation ~2010

For additional info click to see Ogden Chromates meeting report (25Meg)

Status – Non-chrome sealers

Commercial/OEM

- Commercial uses – Various Cr^{3+} and non-Cr alternatives adopted to comply with ELV, WEEE, RoHS
  - Aircraft
  - Vehicles
  - Electronics
  - Fasteners
  - Al alloys
  - Auto and electronic coatings (Zn, ZnNi, ZnFe etc)

DoD

- Alodine 5200/5700 implemented
  - USMC, AVTB Camp Pendleton – wipes for touch-up, repair
  - NASA – Solid rocket booster skins (with non-Cr primer)
  - TACOM Red River MRO
    - Aluminum road wheels for BFV, M113, MLRS
    - M1A1 Abrams tracks

For additional info click to see Ogden Chromates meeting report (25Meg)

TOC

Status – Adhesion promoters

- AC 130/131
  - Boeing implemented on B777 to prevent “rivet rash”, Mar 2007
- Prekote
  - Demonstrated on C-130 WR-ALC
  - Authorized by USAF Tech Order 1-1-8
- AC 130/131 successfully flight tested on F-15, KC-135

For additional info click to see Ogden Chromates meeting report (25Meg)

Projects, data – Chromate alts

Projects

- ESTCP WP-0025 TCP validation
  - Phase 1
  - Phase 2 intermediate
  - Phase 2 Final in draft
  - Non-chromate toxicology
- SERDP fundamental studies of non-chromate corrosion inhibition (begun 2008)
  - WP-1618 – Rare earth inhibitors
  - WP-1619 – Conversion by phosphates and organics
  - WP-1620 – Non-chromate inhibitors
  - WP-1621 – Non-chromate inhibitors
- SERDP fastener coating systems (begun 2008)
  - WP-1615 PVD coatings
  - WP-1616 Pulse plated ZnNi
  - WP-1617 Plate + polymer system
- SERDP PP-1148 Conducting polymers
- USAF Aging Aircraft Systems: Advanced Aircraft Corrosion Protection (AACP) program (summary briefing, Boeing)

Data

- See WP-0025 at left, AACP above

Implementations – Chromate alts

Alternative	Organization	System	Subsystem	Notes
Trivalent				
Alodine 5900 (TCP)	FRC-E	Navy helicopters	Al skin	All helicopter repainting since Jan 06
Non-chrome				
Alodine 5700	USMC, AVTB Camp Pendleton	EFV	Various	Alodine 5700 wipes implemented 2005 (repair, touch-up)
Alodine 5700	NASA	Solid rocket boosters	All 2219, 6061, and 7075 components	Implemented 2002, with Hentzen non-Cr primer. First flight 2002
Alodine 5200/5700	TACOM	BFV	Al road wheels	AA2024-T4 and AA2014-T6 alloys. Overhaul at Red River Army Depot since 2003
		M113	Al road wheels	
		MLRS	Al road wheels	
		M1A1	Al tracks	
AC-131	Boeing	B777	Al skin	Adopted March 2007 to eliminate "rivet rash"

Best options, gaps – Chromate alts

Substitution

- Trivalent sealers (TCP, Alodine 5900)
  - Implemented on aircraft
- Non-chrome sealers (eg Alodine 5200/5700)
  - Implemented on vehicles
- Adhesion promoters (painted systems only)
  - Prekote
  - AC130/131, B777 implementation

Control

- PPE for aircraft, vehicle painting
- Enclosed lines for dip coating

Gaps

- Qualification of non-chromates
- 2000 and 7000 series Al alloys remain difficult to treat
- Electrical cabinets (unpainted Al)
- High frequency conductivity of non-chromate treatments
- Bond primers
- Wash primers (steels, Army)
- Fastener coating systems
- Understanding of protection mechanisms
- Reliable accelerated corrosion test methods

For additional info click to see Ogden Chromates meeting report (25Meg)

TOC

SERDP
Strategic Environmental Research and Development Program

ESTCP
Environmental Security Technology Certification Program

CHROMATED PRIMERS

TOC

Options – Chromated primers

Substitution, control options					Best DoD options	Projects			Gaps	Implementation
Current tech Options	Commercial Status	DoD Status								
		R&D	Qual	Prod		Unsuccessful	On-going	Successful		
Non-Cr primers	Commercial aircraft				Application-dependent				Validation, qualification needed. Fully non-Cr6+ paint system needed	F-35, Apache, EFV, NASA
Deft 44GN098 Non-Cr primer over chromate pretreat	Production (F-35)					Extensive Lockheed cabinet and a/c carrier testing for F-35				
	Boeing Mesa Apache MRO, Longbow upgrade									
Total chromate-free paint system	F-35 by 2009	NASA solid rocket boosters				F-35 validation of non-Cr^{6+} system				
MIL-PRF-23377J Class N non-Cr primer		USMC EFV internal spaces, wet installs								
Mg-rich primer						ESTCP WP-0731				
UV and low temp cure powder coats						SERDP completed, ESTCP ongoing				

Description, current technology – Chromated primer

Technology and usage

- Primer contains chromate for corrosion protection
  - Na, Zn, Sr chromates, etc
- Usage
  - Most corrosion-prone weapons systems
    - Aircraft skins, airframes, landing gear and hydraulics
    - Vehicles and ships

ESOH and technical issues

- Worker exposure during OEM and MRO
- Maintainer exposure during scuff-sand and repaint
- Regulations
  - EPA Clean Air Act
  - OSHA Cr^{6+} PEL
  - ELV, WEEE, RoHS, REACH

Description – Non-chrome primer

- Various commercial formulations:
  - MIL-PRF-85582 (water-borne epoxy)
    - PPG EWDY048A
    - Deft 44GN098
  - MIL-PRF-23377 (high solids)
    - Deft 02GN084
    - Hentzen 16708TEP
- Use of rare earth inhibitors, usually including Ce
- Mg-rich primer (Akzo Nobel)

F-35 non-chrome primer, Deft 44GN098

Status – Non-chrome primer

Commercial/OEM

- Commercial aircraft use includes
  - JAL, KLM, Swissair, Air France
- F-35
  - All internal bays (external coatings are LO)
- Boeing Mesa
  - Apache MRO and Longbow upgrade – Deft 44GN098

DoD

- NASA solid rocket boosters
- USMC EFV internal spaces, wet installs
- Ground support equipment (MIL-C-53022)

Projects, data – Non-chrome primers

Projects

- Extensive Lockheed F-35 development, testing
- USAF Aging Aircraft Systems: Advanced Aircraft Corrosion Protection program (AACP)
- Low temperature powder cure coatings
  - SERDP WP-1268
  - ESTCP WP-0614
- ESTCP WP-0731: Mg-rich primers
- ESTCP WP-0801: UV cure powder coatings
- ESTCP WP-0804: UV cure powder coatings

Data

- Lockheed-Martin F-35 performance data not available
- SERDP WP-1268: Limited data (ESTCP project WP-0614 ongoing)

Implementations – Non-Cr primers

Alternative	Organization	System	Subsystem	Notes
Deft 44GN098	Lockheed	F-35	Interior bays	All internal spaces
	Boeing Mesa	Apache helicopter	Skin	All external panels - overhaul and upgrade
Hentzen non-chromate primer	NASA	Solid rocket boosters	All 2219, 6061, and 7075 components	Implemented 2002, with Alodine 5700 pretreat. First flight 2002
MIL-PRF-23377J Class N non-Cr primer	USMC	EFV	All interior and wet installs	

Best current options, gaps – Non-Chrome Primer

Substitution

- Depends on application
  - Chromated systems usually better than non-chromated, but non-Cr^{6+} has greatly improved recently
- Chromate primer over non-chromate sealer
  - Current NAVAIR requirement
- Non-chrome primer over chromated conversion coat
  - Good intermediate step with minimal Cr^{6+} and equivalent performance in many applications
  - Currently used on F-35
  - Uses minimum Cr^{6+} as pretreat far thinner than primer
- Long-term: Single-component low temperature powder coat with inhibitor may provide better performance

Control

- PPE

Gaps

- Internal fuel tank coatings
- Fully chromate-free paint system with better or equal performance
  - F-35 development, testing in process
  - More difficult (longer term) on 2000 and 7000 series alloys

SERDP
Strategic Environmental Research and Development Program

ESTCP
Environmental Security Technology Certification Program

MAGNESIUM ALLOY TREATMENTS

TOC

Options – Mg alloy treatments

Substitution, control options					Best DoD options	Projects			Gaps	Implementation
Current tech Options	Commercial Status	DoD Status								
		R&D	Qual	Prod		Unsuccessful	On-going	Successful		
High voltage (Tagnite)	OEM aero, vehicle, mil and commercial Mg gearboxes				✓	NAVAIR testing of NDI through Tagnite			FPI validation needed. Al coatings on steel inserts. TCP/NCP qual	
Brush Tagnite	OEM repair, a/c, vehicles	Authorized by NAVAIR			✓					
Cold spray Al						Cold spray Al for repair				
CONTROL OPTIONS										
Segregated line					N/A					
Enclosed line					N/A					
Outsourcing										

Description, current technology – Mg alloy pretreatments

Technology and usage

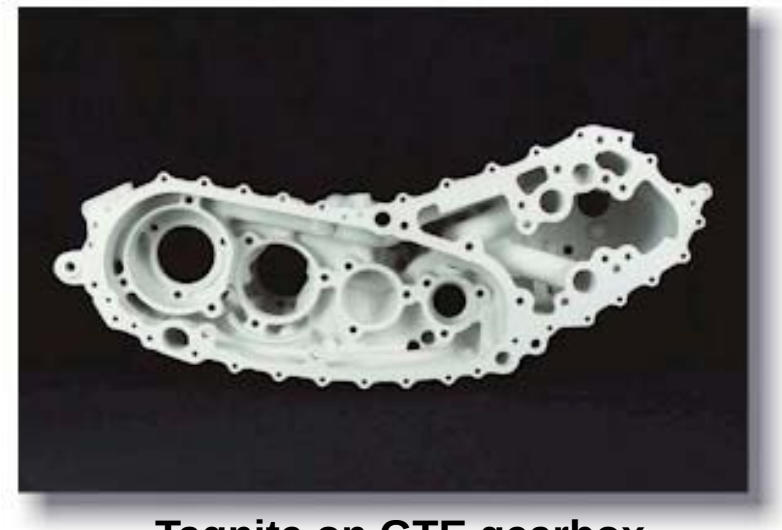
- Mil-M-45202
  - Dow 17, OEM chromate coating (Type I Class A)
- AMS M-3171
  - DOW 19 chromate conversion coating (Type VI)
  - Dow 7 chromate conversion coating (Type III), depot MRO
  - Iridite 15 (Type VIII), depot MRO
- Used for OEM and MRO
  - Gearboxes

ESOH and technical issues

- Worker exposure during OEM and MRO
- Maintainer exposure during corrosion control and repaint
- Regulations
  - EPA Clean Air Act
  - OSHA Cr^{6+} PEL
  - Potential REACH

Description – Mg alloy treatments

- Tagnite is standard commercial Mg treatment
  - High voltage anodizing method
  - Mixed oxide corrosion barrier
  - Brush Tagnite for repair
  - Tagnite cannot be applied to Mg alloys with Cd-plated inserts, so primary use is OEM



Tagnite on GTE gearbox

Status – Mg alloy treatments

Commercial/OEM

- Tagnite used for many Mg gearboxes for helicopters and vehicles (Sikorsky, Allison Transimission), eg
  - CH53 Oil sump housing
  - F-22 F119 GTE gearbox
  - All EFV Mg castings (finish spec)

DoD

- Tagnite 8200 authorized by NAVAIR Aug 2006
- Tests ongoing for Alodine 5700 and 5900
  - Looks promising

Projects, data – Mg alloy treatments

Projects

- NAVAIR projects
  - Alodine 5900 and 5700 appear better than Dow 7 for repair
  - Assessment of NDI of Tagnited Mg alloy components
- ESTCP WP-0620 Cold spray for Mg component repair

Data

- Engineering data not yet available

Implementations – Mg alloy treatments

Alternative	Organization	System	Subsystem	Notes
Tagnite	Sikorsky	CH-53	Mg sump pump housing	In production since 1996
	P&W	F-119 engine for F-22	Mg gearbox	
	Messier-Dowty	MD-500E, 500F, 520N, 600N	Mg gearbox	All gearboxes for M-D commercial helicopters
	General Dynamics	Expeditionary Fighting Vehicle (EFV)	Mg castings	20 castings per vehicle

Best current options, gaps – Mg alloy treatments

Substitution

- OEM Tagnite, with brush Tagnite for repair

Control

- None

Gaps

- Legacy systems:
  - TCP and NCP (Alodine 5700, 5900) in place of Dow 9, 17
  - Not yet fully proved
- Tagnite for legacy systems requires Al-coated inserts
  - Al-coated insert qual needed
- NDI on Tagnited surfaces
  - Used by OEMs
  - Needs NAVAIR qual

SERDP
Strategic Environmental Research and Development Program

ESTCP
Environmental Security Technology Certification Program

CHROMIC ACID ANODIZING (CAA)

Options – Chromic acid anodizing

Substitution, control options					Best DoD options	Projects			Gaps	Implementation
Current tech Options	Commercial Status	DoD Status								
		R&D	Qual	Prod		Unsuccessful	On-going	Successful		
Thin film sulfuric acid anodizing	Production, commercial	Evaluation, NAVAIR			✓				Clear options for paint adhesion	Boeing commercial and military a/c
Boric sulfuric acid anodizing	Production, Boeing	Evaluation, NAVAIR			✓					
High voltage (Keronite)	Commercial, non-aero									
CONTROL OPTIONS										
Segregated line										
Enclosed line										
PPE										

Description, current technology – Chromic acid anodizing

Technology and usage

- Al hard corrosion-resistant coating
  - Improved paint adhesion
  - Note: coating does not contain chromate

ESOH and technical issues

- Worker exposure during anodizing operations
- Regulations
  - EPA Clean Air Act
  - OSHA Cr^{6+} PEL

Description – CAA Alternatives

- Boric Sulfuric Acid Anodizing (BSAA)
  - Boeing process
  - Requires dilute chromic acid seal
  - No performance issues in 15+ years of use
- Thin Film Sulfuric Acid Anodizing (TFSAA)
  - Widely used by NAVAIR and included in MIL-A-8625F
  - Validated SERDP PP-66 (1997)
- Keronite
  - Commercial high voltage anodize for Al that creates mixed oxides
  - No known aerospace uses

Status – CAA alternatives

Commercial/OEM

- Boeing
  - Used on all commercial a/c
  - Used in place of MIL-A-8625 Type I, IB, IC on painted components
  - Lower fatigue
- Some OEMs still require CAA for paint adhesion

DoD

- OC-ALC has replaced CAA with MIL-A-8625 Type 1C, Thin Film Sulfuric Acid anodizing
  - Same at North Island and other depots
- MIL-A-8625F (1988) allows TFSAA in place of CAA

Projects, data – CAA alternatives

Projects

- None known

Data

Implementations – CAA alternatives

Alternative	Organization	System	Subsystem	Notes
Thin Film Sulfuric Acid Anodize, TFSAA (MIL-A-8625 Type IIB)	Boeing	Defense products		
Boric Sulfuric Acid Anodize, BSAA (MIL-A-8625 Type IC)	Boeing	All commercial aircraft	Various	15 years experience in commercial fleet

Best current options, gaps – CAA Alternatives

Substitution

- TFSAA
- BSAA

Control

Gaps

- Clear data showing equivalence in paint adhesion

SERDP
Strategic Environmental Research and Development Program

ESTCP
Environmental Security Technology Certification Program

METALLIC-CERAMICS

Options – Metallic-ceramics

Substitution, control options					Best DoD options	Projects			Gaps	Implementation
Current tech Options	Commercial Status	DoD Status								
		R&D	Qual	Prod		Unsuccessful	On-going	Successful		
Cr^{6+}-free metallic ceramics	Used in Europe, Canada. Various OEM GTE quals				✓	Depot qual testing (OC-ALC)			DoD validation, qualification	GTEs Europe, Canada
CONTROL OPTIONS										
Segregated line										
Enclosed line					Used now					
Outsourcing					Used now					

Description, current technology – Metallic-ceramics

Technology and usage

- MIL-C-81751 ceramic slurry coating with Al flakes
  - Developed by SermaTech and originally sold as SermeTel W
  - Other versions available
  - Sprayed onto engine components, heat treated, grit blasted
  - Sealed with ceramic sealer
- Widely used for hot GTE components for abrasion and oxidation resistance
- Some usage for structural components
  - F-22 landing gear in place of Cd

ESOH and technical issues

- Spray solution contains high levels of Cr^{6+}
  - Heat treat removes most Cr^{6+}
- Applicator exposure to fumes
  - Spray booth
  - PPE required
  - Limited daily exposure
- Regulations
  - OSHA Cr^{6+} PEL

Description – Metallic-Ceramic alts

- Expiration of patent has led to a number of new entrants
- OSHA Cr^{6+} PEL has led to strong efforts at replacement
- Several low-chrome and no-chrome versions available commercially
  - Same basic approach and similar chemistry, but reduced or no Cr^{6+} in basecoat and/or topcoat

Status – Metallic-ceramic alts

Commercial/OEM

- New non-Cr^{6+} and low-Cr^{6+} versions from various vendors have been approved and are in production use
  - SermeTel CF
  - Ipcote
  - Alseal 5000/5200
  - Ceral 3450
    - Approved by GE Power, P&W Canada, Snecma, Standard Aero, Rolls Royce, Siemens

DoD

- Various testing with varied results
- Ceral 3450 implementation under way at OC-ALC

Projects, data – Metallic-ceramic alts

Projects

- Several projects testing SermeTel W alternatives
  - Variable results

Data

- Ceral tested under Foreign Comparative Technology Program
  - Being implemented at OC-ALC
- Vendor testing of SermeTel CF

Implementations – Metallic ceramics

Alternative	Organization	System	Subsystem	Notes
Ceral 3450	GE (power), Rolls Royce, Snecma, Standard Aero (Canada), Siemens, P&W Canada	GTEs		Qualified SermeTel W alternative. 0.0125wt% Cr^{6+} (low Cr) in liquid, <10ppm ("no Cr") in coating

Best current options, gaps – Metallic-ceramic alts

Substitution

- Ceral 3450
- SermeTel CF or equivalent

Control

- Fume hood and PPE

Gaps

- Independent (DoD) testing still needed to verify performance

SERDP
Strategic Environmental Research and Development Program

ESTCP
Environmental Security Technology Certification Program

CHROMATED SEALANTS

TOC

SERDP
Strategic Environmental Research and Development Program

ESTCP
Environmental Security Technology Certification Program

Options – Chromated Sealants

Substitution, control options						Best DoD options	Projects			Gaps	Implementation
Current tech Options	Commercial Status	DoD Status									
		R&D	Qual	Prod			Unsuccessful	On-going	Successful		
Non-Chromated sealants	Boeing Commercial hot melt for butt joints					✓				Significant RDT&E and validation needed	Commercial a/c
	Non-chromated sealants, tapes. Boeing C-17 and other military a/c	Some MRO use on aircraft				✓					C-17 , DoD a/c MRO
Pre-coated fasteners						✓	Pre-coated fasteners to replace wet-install				
CONTROL OPTIONS											
Segregated line						N/A					
Enclosed line						N/A					
PPE											

TOC

Description, current technology – Chromated sealants

Technology and usage

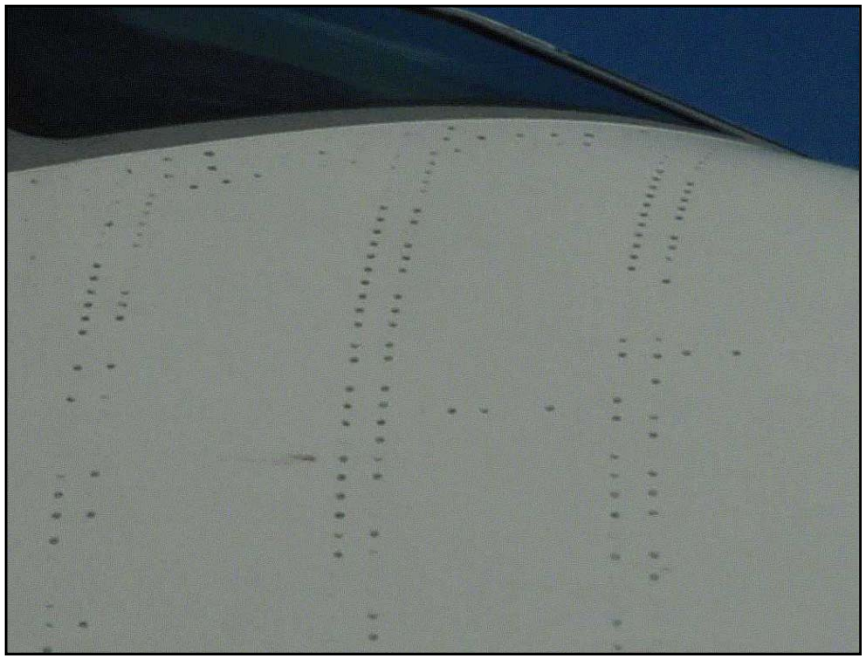
- Mil-S-81733
- Sealants used on interior and exterior joints of aircraft, other systems, to prevent water penetration and corrosion
  - Faying
  - Filleting
  - Butt-gap
  - Tape
- Wet-install fasteners, rivets, etc. one of the most common interior and OML uses of sealants

ESOH and technology issues

- Maintainer exposure to Cr^{6+} during MRO touch-up, repaint, wet-install of fasteners
  - OSHA Cr^{6+} PEL
  - Cr^{6+}-contaminated waste
    - Removed old sealant, excess new sealant
    - Process variability in wet install
- Chromated material
  - Maintainer exposure on accessing sealed spaces
  - Potential RoHS, REACH compliance issues (not currently with aircraft)

Description, alternatives – Non-chromated sealants

- Non-chrome sealants
- Hot melt sealants
- Non-chrome sealing tapes
- Pre-coated fasteners
  - Reduces personnel exposure even if chromated
  - Non-chromated eliminates exposure



Status – Non-chrome sealants

Commercial/OEM

- Chrome-free tapes
  - Gore Skyflex used on A340, B737, B757
    - Implemented on C-17 in 1997
  - Kent H. Landsberg #T-1416 neoprene tape-type sealant
    - Implemented on C-17 in 2000
- Fiber-Resin HL-6414-X hot-melt adhesive
  - Used on Boeing commercial aircraft

DoD

- Skyflex approved for
  - A-10, B-1, B-52, C-5, C-17, C-130, C-141, EA-6B, E-2, E-3, E-6

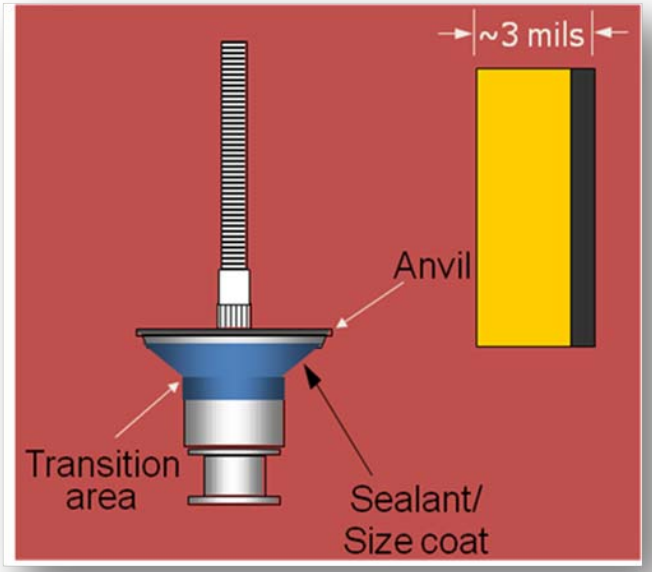
Projects, data – Non-chrome sealants

Projects

- NAVAIR: Pre-coated fastener evaluation
  - SBIR Phase II on SMRC QwikSeal non-chromated system
    - JSF JPO Small Business Tech Insertion project to develop QwikSeal fastener-coating equipment, in progress
    - SBIR Phase II on METSS
- Boeing C-17: various non-chrome sealant testing, implementation

Data

- No known qualified engineering data available



QwikSeal pre-coated fastener

Implementations – Non-Cr sealants

Alternative	Organization	System	Subsystem	Notes
Gore Skyflex tape	Airbus, Boeing	A340, B737, B757	Various	
	DoD	A-10, B-1, B-52, C-5, C-17, C-130, C-141, EA-6B, E-2, E-3, E-6	Various	
	Boeing	C-17	Various	Implemented 1997
Kent H. Landsberg tape-type sealant		C-17	Various	Implemented 2000
Fiber-Resin HL-6414-X hot-melt adhesive		Commercial a/c	Various	

Best current options, gaps – Non-chromate sealants

Substitution

- Non-chrome sealants and tapes when qualified
- Precoated fasteners
  - Reduced exposure and waste even when chromated

Control

Gaps

- Significant testing and validation required for most sealants
  - Many varied applications
  - Additional requirements for filled sealants for use in LO systems

SERDP
Strategic Environmental Research and Development Program

ESTCP
Environmental Security Technology Certification Program

CHROMATED WASH PRIMER

TOC

Options – Wash Primer

Substitution, control options					Best DoD options	Projects			Gaps	Implementation
Current tech Options	Commercial Status	DoD Status								
		R&D	Qual	Prod		Unsuccessful	On-going	Successful		
None		No alternatives			None				Wash alternative needed for Army vehicles	None
CONTROL OPTIONS										
Segregated line										
Enclosed line										
Outsourcing										

Description, current technology – Wash Primer

Technology and usage

- Chromated wash used for paint adhesion on high hard steel (armor) and Al
  - Army vehicles

ESOH and technology issues

- Maintainer exposure to Cr^{6+} during wash
  - OSHA Cr^{6+} PEL
- Chromated surface
  - Maintainer exposure on scuff-sand and corrosion repair operations
  - Potential RoHS, REACH compliance issues

Description, alternatives – Wash Primer

- None

Status – Wash Primer

Commercial/OEM

- None

DoD

- Chromated wash primer has been eliminated as not necessary on some systems
- No alternatives found

Projects, data – Wash Primer

Projects

- None

Data

None

Implementations – Wash primer

Alternative	Organization	System	Subsystem	Notes
NONE				

Best current options, gaps – Wash primer

Substitution

- None

Control

Gaps

- No current alternative
  - Except eliminated as inessential for some systems

SERDP
Strategic Environmental Research and Development Program

ESTCP
Environmental Security Technology Certification Program

SLIDES FOR COPYING

TOC

SERDP
Strategic Environmental Research and Development Program

ESTCP
Environmental Security Technology Certification Program

[TECHNOLOGY]

SERDP
Strategic Environmental Research and Development Program

ESTCP
Environmental Security Technology Certification Program

Options - ??

Substitution, control options					Best DoD options	Projects			Gaps	Implementation
Current tech Options	Commercial Status	DoD Status								
		R&D	Qual	Prod		Unsuccessful	On-going	Successful		
					✓					
CONTROL OPTIONS										
Segregated line										
Enclosed line										
Outsourcing										

Description, current technology – ????

Technology and usage

ESOH and technical issues

SERDP
Strategic Environmental Research and Development Program

ESTCP
Environmental Security Technology Certification Program

Description, alternatives – ??

Status – ??

Commercial/OEM

DoD

Projects, data – ??

Projects

Data

Implementations – ??

Alternative	Organization	System	Subsystem	Notes

Best current options, gaps – ??

Substitution

Control

Gaps